MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2018/2019

ENT4066 – NANOELECTRONICS MATERIALS AND DEVICES
(NE)

24 OCTOBER 2018
2.30 p.m. – 4.30 p.m.
(2 Hours)

INSTRUCTION TO STUDENTS

1. This examination paper consists of 5 pages with 4 questions only.
2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

QUESTION 1

(a) (i) Provide the definition for each of the terms in **Table Q1(a)** below:

Table Q1(a)

Term	Definition
Nanotechnology	
Nanocrystal	
Quantum dot	
Nanocomposite	

[4 marks]

(ii) What are the **TWO** principal factors that cause the properties of nanomaterials to differ significantly from other bulk materials? [2 marks]

(iii) Nanomaterials have a relatively larger surface area when compared to the same volume or mass of the material produced in a larger form. Prove the above statement considering an example for nanoparticle compared with a larger particle. [4 marks]

(b) (i) Explain how the magnetic properties of nanomaterials differ from that of bulk materials. [3 marks]

(ii) With the aid of diagrams, illustrate the density of state (DOS) for bulk, quantum well, quantum wire and quantum dot nanomaterials. [1 x 4 marks]

(c) (i) Explain the relation between the '***Gibbs Free Energy***' and '***critical size***' of a homogenously nucleated nanoparticles. [3 marks]

(ii) With the aid of a diagram, explain how "under cooling" results in formation of a large quantity of stable nuclei crystals. [5 marks]

Continued.....

QUESTION 2

(a) Briefly describe the electron behaviour and optical emissions due to surface plasmonic effect of a metallic nanoparticle. [3 marks]

(b) Besides surface plasmonics and exciton Bohr radius, which are other colour generation mechanisms which can be induced by nanoparticles? [3 marks]

(c) The chiralangle (θ) and diameter (d) of a carbon nanotube (CNT) is given by:

$$\theta = tan^{-1}\left[\frac{\sqrt{3}m}{m+2n}\right]$$

$$d = \frac{\sqrt{3}a_{cc}\sqrt{(m^2+n^2+mn)}}{\pi}$$

respectively, where m and n are integers governing the chiral vector C, and a_{cc} = 0.142 nm is the carbon bond length. A two-dimensional graphene sheet is rolled-up to form 10-μm, (n=12, m=1) single-wall carbon nanotube (SWCNT).

(i) Calculate the chiral angle and diameter of the SWCNT. [4marks]

(ii) Is this a metallic or semiconductor type of CNT? [1 mark]

(d) Briefly explain the utilization of "***Landauer***" formula in conduction measurement of CNT. [4 marks]

(e) **Figure Q2(e)** shows density of state of materials in different dimensions. Explain "Van Hove Singularities" based on the **Figure Q2(e)**. [3 marks]

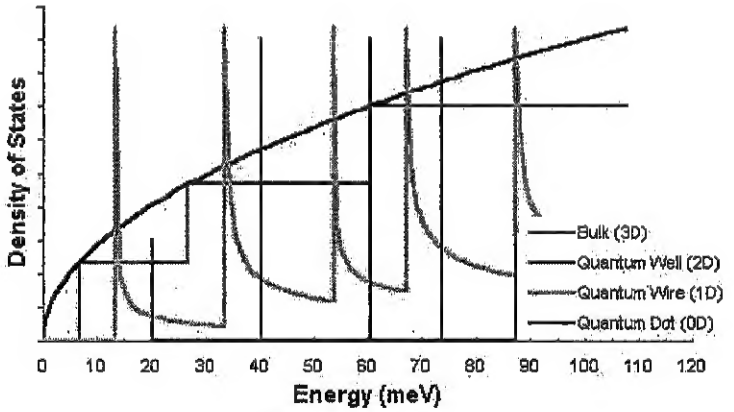

Figure Q2(e)

(f) (i) Explain the relation between "energy gap" and "diameter of nanotube" using a Kataura plot. [3 marks]

(ii) By means of energy band structures as a function of density of states, explain how the metallic and semiconductor CNT are defined in a Kataura plot. [4 marks]

Continued.....

QUESTION 3

(a) Explain how grapheme, a two dimensional (2D) semiconductor exhibit strange behavior compared to typical 2D semiconductors. [3 marks]

(b) Arc discharge is a high temperature dependent method used to fabricate carbon nanotube (CNT). With the aid of a suitable diagram, write a short note about the fabrication process of CNT using "arc discharge" method. [2 + 4 marks]

(c) (i) In the context of device miniaturization explain **THREE** scaling fields. [3 marks]
(ii) What are the challenges on fabrication of gate oxide thickness of CMOS structure in nanoscale? [3 marks]
(iii) What is dielectric constant (k). Briefly explain how **"subtractive porosity"** can reduce the density of the material. [1 + 3 marks]

(d) High-k dielectric materials have been considered to replace the conventional SiO_2 as the gate insulator in nano-CMOS. Briefly describe the requirements for choice of high-k dielectric. Name one successful gate-insulation material and sketch its integration scheme. [3 marks]

(e) In a partially depleted (PD) silicon on insulator structure, explain why floating body effects (FBE) is not desirable. [3 marks]

Continued.....

QUESTION 4

(a) Resonant Tunneling Diodes (RTDs) with negative differential resistance (NDR) characteristics, have the potential to improve the circuit performance by combining conventional devices.

(i) Explain why RTD are very attractive in improving device performance. [3 marks]

(ii) With the aid of a diagram explain differential resistance (NDR). [2 marks]

(iii) The capacitance of a nanosized island used in a single-electron transistor (SET) is given by $C=2\pi\varepsilon\varepsilon_o d$, where d (12 nm) is the diameter of island, $\varepsilon=4$ and $\varepsilon_o = 8.89\text{x}10^{-12}$ F/m. Calculate the temperature limit for SET effect. Given that Boltzmann's constant is $1.38066\text{x}10^{-23}$ J/K. [3 marks]

(b) (i) Consider two thin metallic electrodes (D and S) acting as tunnelling junctions and the voltage drops on the two tunnelling junctions are denoted as V_D and V_S. Sketch an equivalent Single-Electron Transistor (SET) circuit. [3 marks]

(ii) In a single-electron transistor circuit, if 'e' represent the number of electron and C_{tot} is the total capacitance, derive that the threshold voltage (V_{th}) is given by e/C_{tot}. [4 marks]

(c) Usually electrons move continuously in the common transistors, but as the size of the system goes down to nanoscale electron moves one by one. Explain the reason behind the phenomenon with proper diagram. [4 marks]

(d) What are the **THREE** geometries of Organic field-effect transistors (OFETs). Explain how OFET can contribute to lost cost electronic circuits development. [3 + 3 marks]

End of Paper.